Project Abstract

Agricultural Decision-Making in Indonesia with ENSO Variability: Integrating Climate Science, Risk Assessment and Policy Analysis

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The objective of this project is to assess the potential impacts of El Nino-Southern Oscillation (ENSO) events on precipitation and agricultural production in Indonesia under conditions of global warming. The project entails three steps: 1) the construction of empirical downscaling models (EDMs) that link output from global climate models (or general circulation models, GCMs) with regional-scale precipitation more suitable for the specific study of Indonesia; 2) the statistical linking of these downscaled rainfall patterns with agricultural production in Indonesia; and 3) the construction and application of a risk-assessment framework for analyzing critical thresholds of climate impact and adaptation strategies for coping with changed climate conditions in the agricultural sector. An important challenge is to understand and quantify the magnitude and patterns of uncertainty that propagate through each step of the analysis.

Most of the work in the first year has focused on step 1 (above): developing plausible estimates of the climate—and in particular, precipitation—over Indonesia under future climate scenarios. Unfortunately, GCMs are notoriously poor at simulating the hydrological cycle in tropical regions, especially over the Maritime Continent (including Indonesia). GCMs, however, do a reasonably good job reproducing large-scale circulation in the tropics, which is highly related to the hydrological cycle. A primary task during the first year of our research has thus been to develop and evaluate a series of empirical downscaling models (EDMs) that relate large-scale circulation patterns to regional-scale precipitation in the observed (historical) record. Our results show that the EDMs are skillful in predicting and cross-validating precipitation during the dry season (May-August) and during monsoon onset (September-December). The EDMs appear to have less skill during the wet season and monsoon withdrawal (January through April). These findings are consistent with previous research, and with physical relationships between the hydrological cycle and large-scale circulation.

The EDMs will eventually be used in our project to relate the GCM simulated large-scale circulation to regional hydrology under future climate scenarios. Precipitation over the Maritime Continent is controlled by the seasonal cycle (the monsoon) and by the El Niño – Southern

Oscillation (ENSO). Thus, it is important that future precipitation estimates provide reliable information about both phenomena. To complicate matters, ENSO's influence on precipitation in Indonesia is quite different during different phases of the seasonal cycle. For example, although ENSO produces similar large-scale sea-level pressure (SLP) patterns during the wet and dry seasons over Indonesia, ENSO's influence on precipitation is markedly different during the two seasons. As a result, EDMs that do not distinguish between wet and dry seasons tend to simulate precipitation poorly. Our initial research has shown that the EDMs should reconstruct the seasonal cycle and variability separately, and that this reconstruction is feasible.

An additional complication with using EDMs to predict future climate involves choosing the best large-scale predictor variables with which to relate precipitation and the large-scale circulation in *both* today's climate and in a warmer world (due to increased greenhouse gases). Our working hypothesis is that it is unlikely that an EDM that is trained on the instrumental record from today's climate will be a complete model for estimating the mean changes in regional scale precipitation due to global warming. Specifically, if global warming creates a mean climate change that has no analog in the current climate record, then a downscaling model that is trained entirely from the observed record will not be able to simulate the regional climate changes due to global warming. For example, if increased greenhouse gases create an overall warmer mean climate (as projected by the climate models), there may be an enhanced hydrological cycle due to the atmosphere's ability to 'hold' more water vapor—with little or no change in the circulation patterns. Thus, the average specific humidity (the mass of water vapor per mass of dry air) in the atmosphere may be a good predictor of an overall enhancement of rainfall over Indonesia due to global warming, while circulation changes may be a better predictor of ENSO's influence on precipitation (in both past and future climates). Consistent with this hypothesis, our preliminary research has shown that the sign of predicted precipitation change over Indonesia is sensitive to the choice of predictor variables.

A major research question, then, is: "Which large-scale variables best predict future precipitation over Indonesia?" We can begin to answer this question by using the output from the fourth assessment report (AR4) of the Intergovernmental Panel on Climate Change (IPCC), including present day and future climate simulation output from some 20 GCMs (this number varies depending on which variable is desired). These model simulations provide a valuable resource for identifying which large-scale variables are most useful for predicting future precipitation changes. In this case, we use the same EDM framework to identify relationships between modeled large-scale circulation and modeled *large*-scale hydrology over the Maritime Continent (we are not downscaling, but the statistical techniques are the same). We will then use these model-based 'EDMs' to reconstruct precipitation during the model's future climate scenarios. We are currently developing and evaluating these EDMs within the IPCC AR4 models.

During the first year we have also begun designing the risk assessment framework and matching it to the expected climate model outputs. Specifically, we have been assessing various critical threshold indicators for future climate impacts on agriculture in Indonesia. The threshold indicators that appear to be most plausible include the duration of the monsoon, the percentage of "normal" rainfall (based on a long-run average) in the wet season, and the delay in rainfall onset in the wet season. We have regressed these indicators on rice production in the main harvest season and throughout the crop year using historical data and have found highly significant relationships.

Work in progress

During the second year of our research project, we will design GCM experiments that identify how ENSO influences the large-scale circulation over the Maritime Continent under an altered (future) mean state. As we develop these scenarios, we recognize that an essential component of our risk assessment framework is the quantification and propagation of uncertainty throughout the analysis. Thus, it is important that we design the GCM simulations such that they address the dominant sources of uncertainty in future climate scenarios. We have begun this analysis by exploring the main patterns of uncertainty in the IPCC AR4 model simulations via principal components (PC) analysis. Our initial results have shown that the dominant pattern of uncertainty resembles that of ENSO events.

We are currently preparing a manuscript that explores the skill of the EDMs as a function of season, predictor variable, and statistical technique. We are in the midst of evaluating the different EDMs in the IPCC AR4 models, and will be organizing those results into a separate manuscript over the next year. We have hired a graduate student at the University of Wisconsin to help evaluate how large-scale patterns of variability relate to regional-scale precipitation. The treatment of uncertainty in our climate models remains a major topic of ongoing research.

During year two we will continue to identify other critical threshold indicators, such as the probability of 2-3 consecutive dry years, the number of cloudy days, and temperature extremes. We will need to use longer-run scenarios and crop-based models to determine the strength of these indicators. We also plan to regress the indicators against corn and other non-rice crops that are important for food security in Indonesia. The information from this assessment is being used for the design of climate model output in step 1. Our work will continue to be an iterative process in years 2 and 3. We have also hired a graduate student at Stanford University who is beginning to work on stakeholder assessment of and expert opinion on critical thresholds. She expects to conduct fieldwork on these topics in year 2.

Finally, we are beginning to organize the outreach component of our project. In November 2005, Naylor, Falcon, and Battisti will travel to Indonesia to meet with policymakers in different agencies (e.g., Ministry of Agriculture, Planning, Finance, and Food Logistics) and discuss the use of our model for short- and long-run planning purposes. We will also work with staff within the Food Security branch of the Ministry of Agriculture to transfer the model for ongoing use within the agency.